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CCL REPORT NO. 285

FINAL REPORT

EFFECT OF METALLIC COATINGS AND ZINC RICH PRIMERS
ON THE PERFORMANCE OF FINISHING SYSTEMS
FOR AUTOMOTIVE STEEL

BY

MELVIN H. SANDLER

OCT 16 1970

SEPTEMBER 1970

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Details of illustrations in this document may be better studied on microficho

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U. S. ARMY
ABERDEEN RESEARCH AND DEVELOPMENT CENTER
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ABSTRACT

The effect of metallic coatings and zinc rich primers on the performance of finishing systems for automotive steel was investigated. Galvanized and aluminized type steels and zinc rich primed steels were coated with specification finishing systems and exposed to tropical and temperate environments. Data showed the hot dip galvanized steel properly finished will offer the most effective corrosion resistant system for severe environments such as salt atmosphere and sea coast exposure. This is followed in descending order by aluminized steel, zinc rich primer on cold rolled steel, electrolytic zinc and cold rolled steel. Differences between the metallic coated steels is much less pronounced under less severe exposure.

TABLE OF CONTENTS

	Page No.
TITLE PAGE	i
ABSTRACT	11
INTRODUCTION	1 -
DETAILS OF TEST	2 - 3
DISCUSSION	3 - 4
REFERENCES	4
APPENDIX A	5
Photographs 1 - 5	6 - 10
APPENDIX B	11
Tables - X	12 - 26
APPENDIX C	27
Figures 1 - 5	28 - 32
DISTRIBUTION LIST	33 - 35
DD FORM 1473	36

INTRODUCTION

Military vehicles are exposed to a wide variety of corrosive climatic environments. Among the more severe exposures are salt atmospheres such as sea coast sites and humid tropical weather conditions. In recent years the automotive industry has increased the useage of galvanize steel and zinc rich primers on underbody components such as corner posts, box sections, rocker sections, etc. to reduce corrosion. As a result of the improved corrosion resistance obtained interest was expressed by the U.S. Army Tank-Automotive Center (ATAC) in the possibility of using metallic coated steels for vehicle bodies. In November 1965 the Coating and Chemica! Laboratory was requested by ATAC to conduct an exposure program to determine the effect of metallic coated steels and zinc rich primers on the corrosion behavior of finishing systems for automotive steels exposed to severe climatic conditions.

The tropical sites selected were a breakwater marine (Photo 1) with very high atmospheric salt content, an open field (Photo 2) and a rain forest (Photo 3) located at Fort Sherman, Panama Canal Zone. For temperate zone exposure the test fence (Photo 4) at Aberdeen Proving Ground, Maryland was used. Panama is considered representative of most tropical environments, having consistently high but not extreme temperatures, high humidity, and abundant rainfall. The Fort Sherman area averages approximately 130 inches of rainfall a year with monthly means in the rainy season (May-December) from 12-22 inches and in the dry season (January-April) from 1.4-4 inches. The term dry season can be somewhat misleading since rain normally falls on about half the days. The monthly mean temperatures range from 80-82°F, with a daily range of 8-11°F. The monthly mean relative humidity ranges from 77-86 percent. Although the percentage of cloudiness is high, there are few days without some sunshine. Christobal, just across the bay from Fort Sherman, averages 6.3 hours per day with monthly totals ranging from about 5 hours per day in June, July, and November to about 8 hours per day in March.

The breakwater site is situated at the junction of Limon Bay and the Caribbean Sea and faces North in the direction of the prevailing trade winds. The specimens at this site are exposed to constant spray of salt water with a salt fall for 1 year being calculated as 4514 lb/acre (1). The open field site is approximately 1/2 mile inland from the breakwater and is subject primarily to rain and sun. The rain forest site is approximately 4 miles inland in the tropical evergreen forest composed basically of 3 tiers of tree growth ranging from 20-125 feet in height. The exposure here is primarily humidity and rain. More detailed information on the geography, climate, and description of the test sites is reported by Teitell (2), Chambers (3), McCoullough (4), and Wiley (5).

II. DETAILS OF TEST

- A. Test Specimens All test specimens were 4×12 inch panels of the following metals:
 - 1. Cold rolled steel, No. 20 gage (Federal Specification QQ-S-698).
- 2. Hot dip galvanized cold rolled steel, 20 gage, commercial quality, 1.25 oz./sq. ft.
- 3. Electrolytic zinc coated cold rolled steel with 0.1 mil zinc plate on each side. Minimum coating weight 0.10 oz./sq. ft.
- 4. Aluminized steel, Type I, 20 gage, hot dip coated on both sides with aluminum silicon alloy. Approximate coating weight per side 0.5 ounce per square foot (0.001 inch aluminum per side).

B. Surface Preparation and Finishing.

Metal preparation included solvent cleaning, chemical, and wash primer surface treatments. Four specification primers including an alkyd-phenolic, vinyl, epoxy, and organic zinc rich type and a proprietary inorganic zinc rich were used. The zinc rich types were used only on sand blasted cold rolled steel for comparison to the plated steels. The basic finish coats were olive drab semi-gloss enamel, Specification TT-E-529 and vinyl lacquer MIL-L-14486. A vinyl alkyd enamel, MIL-E-13515, was also used as a finish coat over the zinc rich primers. Surface preparation and finishing systems used are listed in Table I. The test panels were given the applicable pretreatments and the coatings spray applied using an automatic spray apparatus to assure film uniformity. Wash primer, MIL-C-15328, was applied to a dry film thickness between 0.3 and 0.5 mil; zinc rich primers between 2.0 and 2.5 mils; and all topcoats 0.9-1.1 mil except when applied over the proprietary zinc rich primer which required two coats or a thickness of 2.0 mils to obtain a uniform appearance, the first coat being heavily absorbed by the primer.

C. Exposure.

The specimens were placed on exterior exposure at the four test sites. The racks at the breakwater face north in the direction of the prevailing trade winds, those in the open field and rain forest face south. All were mounted at an angle of 30 degrees. The racks at APG face south at an angle of 45 degrees.

D. Evaluation.

At approximately 6 month intervals for up to 40 months the panels were examined for corrosion and/or blistering at the score, and for general surface condition and given a rating from 5 to 0 in accordance with Tables II and III. Examples of the score ratings are illustrated in

Photo 5. In general, ratings of 5 and 4 are considered to provide satisfactory protection. It is realized that panel evaluation cannot always be clearly defined by numerical rating, primarily when the condition of the specimen falls at the border of two possible ratings. Thus the number assigned is left to the judgement of the evaluator. For this reason in most cases the rating of a specimen was not considered complete until it received the same numerical rating for 2 consecutive rating periods. This is of particular concern in ratings of 4 and 3 since the former is considered satisfactory and the latter unsatisfactory. Therefore until two consecutive ratings were the same, the specimen was considered to have the higher rating.

III. DISCUSSION

Reproducibility among replicate specimens was excellent in most cases. Although there are occasional exceptions to be found in the data, it is believed the scope of the program was sufficiently broad to show general trends and to provide a meaningful guide for the selection of suitable finishing systems. Where detailed information on the performance of a specific system is desired, the rating Tables IV-VIII in the appendix may be consulted. Substrate and finishing system effectiveness at each site is illustrated in bar graphs, Figures 1-4, which cover the number of systems remaining with no rating less than 4 at the end of each exposure period. Figure 5 indicates the number of systems remaining at the end of each exposure period with no rating less than 4 at all sites. As expected, from previous exposure studies, the breakwater is by far the severest site with the major cause of failure being corrosion and/or blistering at the score. This is clearly shown in Table IX which lists the percent of systems with ratings less than 4 for each of the rating elements.

The data clearly indicates hot dip galvanize properly finished will offer the most effective corrosion resistant system for severe environments such as salt atmosphere and sea coast site (Figure 1). This is followed in descending order by aluminized steel, zinc rich primer on cold rolled steel, electrolytic zinc, and cold rolled steel. The differences between the metallic coated steels is much less pronounced under less severe exposure (Figures 2, 3, and 4), however, the general order of rating would be the same. This is further illustrated in Figure 5 which tabulates those systems with ratings of 4 or better at all sites. With regard to metal pretreatment prior to painting, wash primer was more effective with the hot dip galvanized steel than the chromate conversion coating under severe exposure of the sea coast whereas comparable performance was noted at the other sites. The reverse of this was true for the aluminum coated steel, i.e., MIL-C-5541 chromate film was more effective than wash primer at the sea coast site. However, as indicated earlier the hot dip galvanized substrate provided the most effective performance with 8 systems still rated 4 or better at all sites after 34 months exposure versus 4 systems utilizing aluminized steel. These systems are listed in Table X.

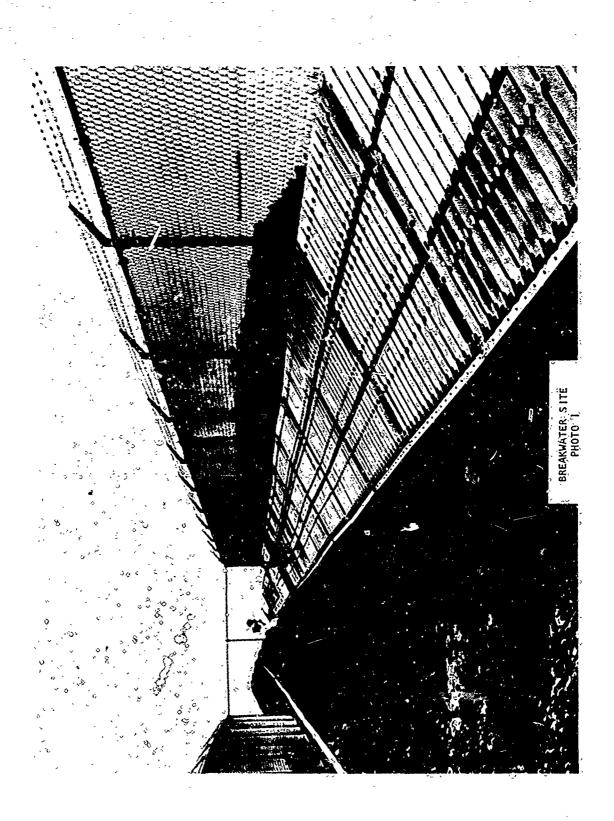
After 40 months exposure 5 of the galvanized systems and 2 aluminized systems were rated 4 or better with systems I - f, g, h and II - c, d,

of Table X having score ratings of 3 at the breakwater. However, these ratings will not be considered complete unless the rating is the same at the next evaluation period, as explained in paragraph II C "Evaluation" above. Regardless of this however, the noted trends have continued.

IV. REFERENCES

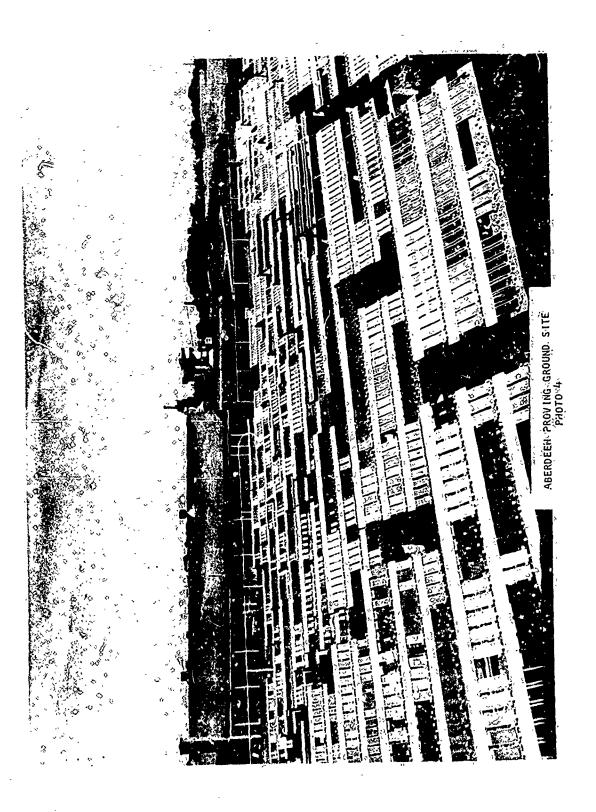
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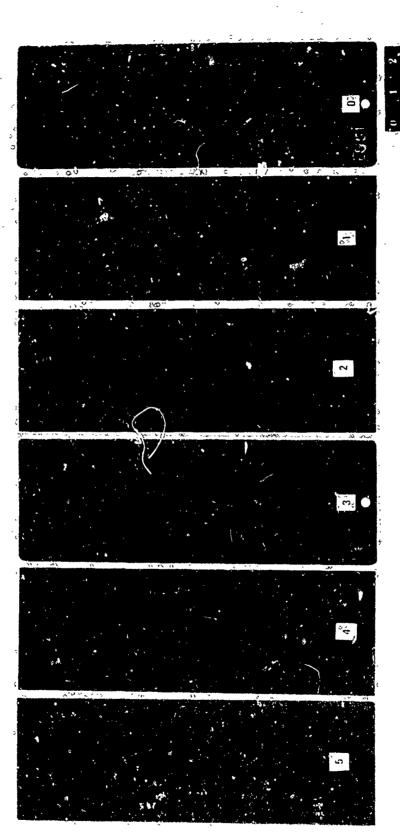
APPENDIX A











ŚCORE CONDITION PHOTOS

ÀPPENDIX. B

LEGEND

BW = Breakwater Site

OF = Open Field

RF = Rain Forest

APG = Aberdeen Proving Ground

R = Combined with number indicates when panels we're removed.

TABLE I - SURFACE PREPARATION - FINISHES

Surface Preparation

Solvent Clean - 1:1 by volume aliphatic naptha (TT-N-95) - ethylene glycol monoethyl ether (TT-E-781)

Sand blast -

MIL-P-15328 - Primer (Wash) Pretreatment (Formula 417 for Metals).
MIL-C-5541 - Chemical Films and Chemical Film Materials for Aluminum and Aluminum Alloys, Type 118 Grade C, Class 2.

Chromate Corrosion - Proprietary for Ganvanize.

TT-C-490 (Type I) - Cleaning Methods and Pretreatment of Ferrous Surfaces for Organic Coatings.

Primers

MIE-P-8585 - Primer Coating, Low Moisture Sensitivity.

MIL-P-15930 - Primer, Vinyl Zinc Chromate Type.

MIL-P-52192 - Primer Coating, Epoxy.

MIL-P-23377 - Primer Coating, Epoxy Polyamide, Chemical and Solvent Resistant.

MIL-P-46105 - Primer Coating; Weld-Trhough, Zinc Rich.

Inorganic Zinc Rich - Proprietary.

Finish Coats

TT-E-529 - Enamel, Alkyd, Semi-Gloss.

MIL-L-14486 - Lacquer, Vinyl Resin, Semi-Gloss.

MIL-E-13515 - Enamel, Vinyi Alkyd, Sami-Gloss.

TABLE II - SCORE RATINGS

1. Score Condition

Rating	Corrosion and/or Blistering
5	None - 1/32 inch
4	1/32 - 1/16 inch
.3	1/16 - 1/8 finch
2	1/8 - 3/16 inch
i	3/16 - 1/4 inch
0	> 1/4 inch

II. Undercutting at Score

Rating	
. 5	None - intermittent
4	Continuous to 1/16 inch
3 .	Continuous to 1/16 - 1/8 inch
2.	Continuous to 1/8 - 3/16 inch
4	Continuous to 3/16 - 1/4 inch
.0	Continuous > 1/4 iñch

TABLE 111 - SURFACE CONDITION* RATINGS

Rating	A. Corrosion Alone	
5 4 3 2 1 0	None: ASTM Photo No. 10, Type I ASTM Photo No. 9, Type I ASTM Photo No. 8, Type I ASTM Photo No. 7, Type I ASTM Photo No. 6, Type I or worse	
Rating	B: Corrosion Accompanied by Blistering	
5	None	
5 4	Trace, less than 5 defects on 4 x 12 inchepanel	
3	ASTM Photo No. 8, Type 2	
3 2. 1.	ASȚMEPĥoto No. 7, Type 2	
	ASTM Phoro No. 6, Type 2	
0.	ASTM Photo No. 4, Type 2 or worse	
Rating	C. Blistering Alone	
5 4	None	
4	Trace	
	ASTM Blister Size 2 on 4x12 inch panel : 2 max.	7.
	ASTM Blister Size 4 on 4x12 inch panel	-
	ASTM Blister Size 6 on 4x12 inch panel	Ľ
	ASTM Blister Size 8 on 4x12 inch panel	-
2	8 max.	
3 2 1	ASTM Few - Record blister size.	
2	ASȚM Medjum - Record blister size. ASTM Med-Dense - Record blister size	
0	ASTM Dense - Record blister size	
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*Select applicable condition.

TABLE IV EXPSOURE RATINGS - HOT DIP CALVANIZE.

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TABLE 1V - Continued

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TABLE VI EXPOSURE RATINGS -- ALUMINIZED STEEL

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face	32 Ure	Coating System	ML-P-15930 TT-E-529			MIL-P-15930		HIL-P-23377	*1-E-529		HIL-P-23377		
Sur	Exp.	Coating	H. 17-6			¥ .		불	-		¥ ¥		
		System No.	Ŋ			9		7			80		1

TABLÉ VIII EXPOSURE RATINGS ÷ COLD ROLLED STEEL - GRIT BLASTED

	Exposure Site	<u> </u>	 	⁷ B₩	 .	E.	" RF		-	OF.	" ,	1	AP.G.	
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System	Coating	Months Exposure	Score	Undercut	Surfacê	Score	Undercut	Surface	Score	Undercut	Surface	Score	Undercut	Surface
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1/	MIL-P-46105	22	ľ	R13	-	5	Š	5	5	5	5	5	5	5
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2	MIL-P-46105	22	2	,2	∂BÒ ³	3				<u> </u>				
-	MIL-P-15328	- 28	. 2	2	Ŗ0	<u> </u> -		_				-		
,	T.T+E-529	34		R28:	`									
	· · · · · ·	40	,		<u> </u>		·/·		v.					_
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		13	5	5.	·B3	- 5	5	5	5	5	5	5	5	5
3	MIL-P-46105	22	5	5	Al	, 5	5	5	5.	.5	·5	5	5	5
	MIL-E-13515	28		R22	•	4	4	5	5	5	5	5	5	5
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;		7	5	5	5		_		,	4	3			
		13	,5	5	ВО	à			j ⁱ .		¥			
4	MIL-P-46105	22		R13						<u></u>		F		
•	MIL-C-15328	28									\	[
ì	MIL-E-13515	34												
		40	<u> </u>											<u></u>
		7	4	4	5	5	5	5	5	5	5	5	5.	5
		13	5	5	A4	5	5	5	5	5	5	5	5	5
5	MIL-P-46105	22	4	4	ВО	5	5	5	5	5	5	5	5	5
	MIL-L-14486	28	4	4	B 1	5	5	5	5	5	5	5	5	5
		34	4	4	во	5	5	5	5	5	5	5	5	5
		40		R34	· · · · · ·	5	5	5	5	5	_5	5	5	_5

TABLE VIII - Continued.

E	xposure Site		<u> </u>	BW:		67°	RF	-2, -2, -	ř—-	0F	<u> </u>	117	APG	
System No.	Coating System	Months Exposure	Score	Undercut	Sunface	Score	Undercut	Surface	Score	Unde rout	Surface	Score	Undercut	Surface
		7	4;	4	5	5	5	5 `	5	້ 5 -	·5	5	5	5
	Inorganic Zinc: ;	, 22	5	5. 1	5 5. (5	`5 r	5° 5′	5	5 4	5 5 .	5	5 4	5 ć
:6)/	, (Self Cure)	28	, 2	2.	5 5	5.	5 5	5	, 4 ;	4	5. 5.	4	4	5 5
	TT-E-529	34	0	0	5	5	5	5 :	'5 '5	5	ي. 5 .	4-	7 4:	,ŝ
	,	40	0	0	.5 .	5	.5	5	5	بر 5.	5 5	4	4	.5 .5
 -		7:	4.	4	5			 -	-	 _		,	7	<u> </u>
	•	13:	5	5	5 \	i.) ·			سندا		
Ĵ.	Inorganic Zinc (Self Cure)	2 2	: 2	2	82	l [·]		3				•		
/ ;	MI'L-P=15328	28	,0	0,	BO .	,			<u> </u>	<u> </u>	` `			
`	TT-E-529	34	ľ	R28	c				·		•			
	v	40			:	·	<i></i>				n	1		
^	*	.7	5	5	5.	-5	5	5	-5	5	5	5	5	5
	Inorganic Zinc .	13-	-5	5	A4- :	5.	5	5	· ·5	5	5	³5 ·	5	5 ´Š
8	(Self Cure)	22 '	·5	5	c3-4.	5	5	5.	4	4.	5	5	5.	5
	MIL-E-13515	28	5	'5	В0	5	5	5	5	5	5	5	Š	5
`		34	5	5	А3	-5	Ë	5 -	5	5	5.	5	5	5
		40	5	.5	A3.	:5	5.	5	. 5	5 .	<u>′5</u>	5	5	5
		7,	5	5	5 ຶ		<u> </u>					,*`	_	`~~``
	Inorganic Zinc	13	5	5	5 .						_			
9	(Self Cure)	22	4	4	c4-8				,	>				
	MIL-P-15328	28	3	3	Α4				<u> </u>					
	MIL-E-13515	. 34	3	3	5									
		40	ļ	R34					ļ					<u> </u>
	7	· 7	4	4	5	5	5	5	5	5	5	5	5	5
	Inorganic Zinc	13	.5	5	5	5	5	5	5	5	5	5	5	5
10	(Self Cure)	22	4	4	5	5	5	5	4	4	5	4	4	5
	MIL-L-14486	28	4	4	В3	5	5	5	5	5	ВŁ	4	4	5
		34	4	4	B1	5	5	5	5	5	5	3	3	5
		40		R34		5	5	5	5	5	5	3	3	5

PERCENT OF SYSTEMS RATED LESS THAN 4
(Total Systems - 106)

			Months			~ ~~ .
Exposure Site	7	13 ^	. 22	28	34	40
	Score Con	dition	<u> </u>			
BW	42	47	56	.57°	55	58
RF	- 1	9	41	16	16.	20
0F	4	8	22	26	29	32
APG	14	26	33	34	33′	36
	Score and Surf	ace Co	ndi ti'o	n Only	-	
BW	5	15	18	23	26	27
RF	0	0.	Ó.	0,	1	-1
ΰ F	1	1	.1.	1	2	2
APG	1	2.	3.	3	4	4
	Surface Co	nditio	on Oňly	÷		
₿W -	^2	é	7	8	8	8 ,
`RF	7 `	8	8	8	. 8	9
°0Ē	1	2	2	2	7	7
APG	3.	22	3	3	3	4
-	Total All	Condi 1	ions			-
BW .	49	68	81	88	8 9	93
RE	8	17	19	24	25	30
OF	6	11	25	29	38	41
APG	18	30	39	40	40	44

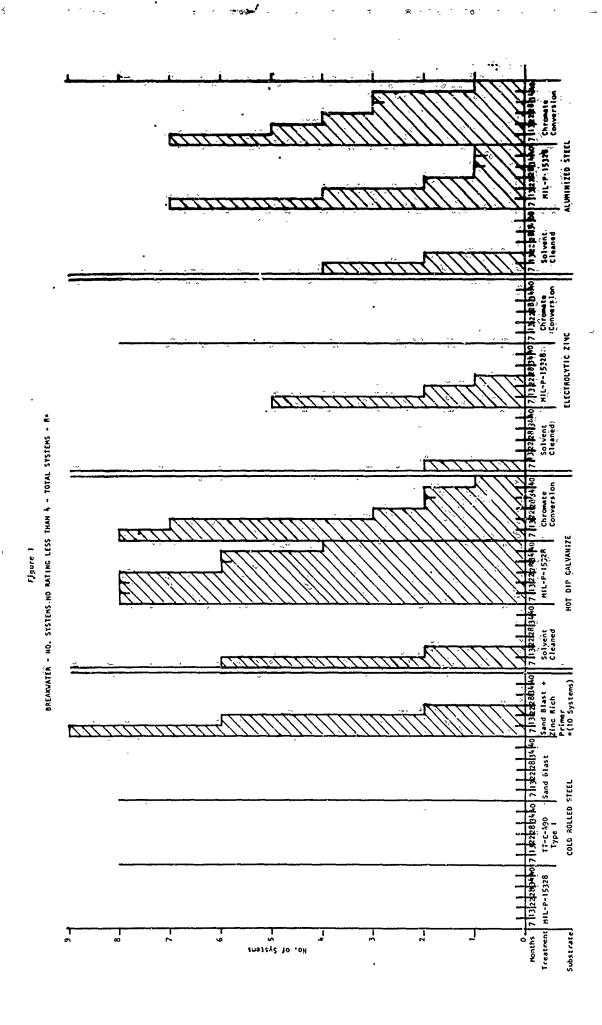
TABLE X

SYSTEMS RATED 4 OR BETTER AT ALL SITES - 34 MONTHS EXPOSURE

1. Hot Dip Galyanize

	Pretreatment	Primer	<u>Topcoat</u>
	<u>M</u> (L-P-15328	MIL-P-8585	TT-E-529
	MIL-P-15328	MIL-P-8585	MIL-L-14486
	M1L=P-15328	MIL-P-52192	TT-E-529
	MTL-P-15328	MIE-P-52192	MIL-L-14486
	Chromate Conversion	MIL-P-52192	TT-E-529
	MIL-P-15328	MIL-P-15930	₹T÷Ĕ−Ś29
	MI E-P-15328	MIL-P-23377	TT-E-529
	Chromate Conversion	MIL-P-15930	TT-E-529
41. A1	uminized Steel		-
	MIL-C-5541	M11-P-8585	M1L-L-14486
	MJL-P-15328	MIL-P-15930	MIL-L-14486
	MIL-C-5541	MIL-P-8585	TT-E-529
	MII - C-55Å1	MII-P-15930	M11-1-14486

APPENDÎX Ĉ



ALUMINIZED STEEL HIL-P-15328 Solvent 7/13/2428/34/40/7/13/22/28/3440 ELECTROLYTEC ZINC Solvent 7 h3222334407 j1322883440 7 l1322883440 c 561vent HIL-P-15328 C Chromate HOT DIP GALVARIZE Sand Blast + Zinc Rich Primer *(6 Systems) TT-C-490 | Sand-Blast Type I COLD ROLLCD STELL MIL .P-15328 Konths Treatment Hox of Systems Substrate

Figure 2. Opeń field – NO. Systems Wiżkyno Rating Less than 4 % total systems – Am

FIGURE 3 RAIN FOREST - ND. STSTENS-VITH NO RATING.LESS THAH 4 - TOTAL SYSTEMS - 84

71322283440 7 1322289340 HIL-P-15328 Chronate ELECTROLYTIC 21HC Solvant HOT DIP GALVAHIZE 7 1 1222263440 Sand Blast COLD ROLLED STEEL 7/13/22/28/24/40 7/13/22/28/34/40 HIL-P-15328 77-C-490 Rooths Treatment Substrate No. of Systems

Flgure 4 APG - NO. SYSTENS WITH NO RATING LÉSS THAY:4.-- JCTAL SYSTENS BA

Electrolytic Galvaníze Total Systems 24th Hot Dip Galvanize *Cold Rolled Steel + Zinc Rich Primer 113% 22 | 28 34 (10 Systems) 1 13 22 28 34 40 Cold Rolled Steel Months 25-Ϋ. 9 202 7

Figure 5 .NO. SYSTEMS 4 OR BETTÉR AT ALL 'SITES

Security Classification

Security Classification		1 5 7 4 4					
	NTROL DATA - RAD		na annaith annait in althurithiúi				
(Security classification of title, body of abstract and indexi							
1. ORIGINATING ACTIVITY (Compare author) U.S. Army Aberdeen Research & Developmen		Unclass ified					
Coating & Chemical Laboratory	· ` ` _	26 GROUP					
Aberdeen Proving Ground, Maryland 21005	1 -	AUDHD '6					
3. REPORT TITLE							
EFFECT OF METALLIC COATINGS AND ZINC RIC SYSTEMS FOR AUTOMOTIVE STEEL	H PRIMERS ON THE	PÈRFO:	RMANCE OF FINISHING				
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	- ^	<u> </u>					
Final Report							
5. AUTHOR(5) (Lass name, first name, initial)							
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ABSTRACT							
The effect of metallic coatings and zinc	rich primers or	n the p	erformance of				
finishing systems for automotive steel w	as investigated.	. Gålv	anized and aluminized				
type steels and zinc rich primer steels	were coated with	ı speci	fication finishing				
systems and exposed to tropical and temp	eraté environmen	ntś. D	ata showed the hot				
dip galvanized steel properly finished w	/ill offer the m	ost eff	ective corrosion				
resistant system for severe environments	s such as sait at	tmospĥé	re and sea coast				
exposure. This is followed in descending							
primer on cold rolled steel, electrolyti							
bétween the metallic coated steels is mu	ich less pronound	ced und	er less severe				
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